Mars Meteorites

Of the 20,000 meteorites that have been discovered on Earth, only 12 have been identified as originating from the planet Mars. These rare meteorites have recently created a stir throughout the world when NASA announced that evidence of microfossils may be present in one of these Mars meteorites,

The meteorites listed below are listed in the order that they were found. It is interesting to note that the last six Mars meteorites discovered were from the Antarctic. The last Mars meteorite found outside of the Antartic was the Zagami meteorite which fell in Nigeria in 1962.

Photos of 11 of the 12 Mars meteorites are provided. I would appreciate if anyone can send me (baalke@kelvin.jpl.nasa.gov) a photo of the Yamato Mars meteorite to complete the set.

Meteorite Name	Location Found	Date Found	Mass (g)	Type
Chassigny	Chassigny, France	October 3, 1815	~4,000	Chassignite
Shergotty	Shergotty, India	August 25, 1865	~5,000	Shergottite
Nakhla	Nakhla, Egypt	June 28, 1911	~40,000	Nakhlite
Lafayette	Lafayette, Indiana	1931	~800	Nakhlite
Governador Valadares	Governador Valadares, Brazil	1958	158	Nakhlite
Zagami	Zagami, Niger	October 3, 1962	~18,000	Shergottite
ALHA 77005	Allan Hills, Antarctic	1977	482	Shergottite
Yamato 793605	Yamato Mountains, Antarctica	1979	16	Shergottite
EETA	Elephant Moraine, Antarctica	December 1979	7,900	Shergottite
ALH 84001	Allan Hills, Antarctica	1984	1,939.9	
LEW 88516	Lewis Cliff, Antarctica	1988	13.2	Shergottite
QUE 94201	Queen Alexandra Range, Atica	1994	12.0	Shergottite

News About Life on Mars

The elongated structure in the center maybe a microfossil

- NEW Stardust Connection with the Martian Meteorite and Life on Mars
- Lecture on Searching For Life in Ancient Water Systems of Mars (Michael Carr - August 22, 1996).
- Possible Source Craters For Martian Meteorite Found (Nadine Barlow - August 12, 1996).
- Water Extracted from Mars Meteorites Provide Clue to Red Planet's Past (NASA - March 3, 1992)
- Statement from Dan Goldin, NASA Administrator (August 6, 1996).

- Signs of Past Life from Mars? (American Association for the Advancement of Science (AAAS) News Release - August 6, 1996).
- Meteorite Yields Evidence of Primitive Life on Early Mars (NASA - August 7, 1996).
- Search for Past Life on Mars (Science article - August 16, 1996)
- President Clinton Statement Regarding Mars Meteorite Discovery (August 7, 1996).
- NSF Statement Regarding Possible Life on Mars (August 7, 1996).
- UNM Sulphur Study Finds No Evidence of Life in Mars Meteorite (Albuquerque Journal - August 8, 1996).
- Life from Ancient Mars?\ Sky & Telescope - August 8, 1996).
- Photos of the potential microsfossils in the Mars Meteorite:
  - http://www.jsc.nasa.gov/pao/flash/
  - http:/fc.nasa.gov/marslife/cu-ames.arc.nasa.gov/marslife/
  - http://rsd.gsfc.nasa.gov/marslife/
- Life on Mars (Space Policy Project)
- CyberSpace News (National Space Society)
- Space Views (National Space Society - Boston Chapter)
- Meteorites from Mars! (Johnson Space Center)
- SNC Meteorites (Caltech)

Future Missions to Mars

- Mars Global Surveyor (NASA - Launch in Nov 1996)
- Mars 96 (Russia - launch in Nov 1996)
- Mars Pathfinder (NASA - Launch in Dec 1996)
- Mars Surveyor 98 (NASA - Launch in 1998)
- New Millennium (NASA - Launch in 1998)
- Planet B (Japan - launch in 1998)

Please direct questions and comments about this home page to
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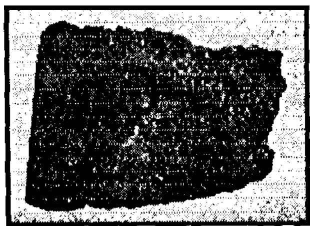
The Zagami Meteorite


6K

The Zagami Meteorite
Copyright Bethany Sciences
New Haven, CT

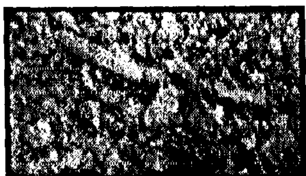
Meteorite: Zagami
Location: Zagami, Katsina Province, Nigeria
Fell: October 3, 1962
Type: Shergottite (SNC)

On an October afternoon in 1962, this meteorite landed about 10 feet away from a farmer who was trying to chase crows from his corn field. The farmer heard a tremendous explosion and was buffeted by a pressure wave. After a puff of smoke and a thud, the meteorite buried itself in a hole about 2 feet deep. Weighing at about 18,000 grams (40 pounds), the Zagami meteorite is the largest single individual Mars meteorite ever found.


133K

A slice of the Zagami Meteorite
Copyright 1995 Ron Baalke

The meteorite was sent to the Kaduna Geological Survey and placed in a museum. Some years later, Robert Haag, a meteorite dealer, traded for a large portion of the Zagami meteorite. The Zagami meteorite is the most easily obtainable SNC meteorite available to collectors.


8K

Another closeup of Zagami
Photo courtesy of the New England Meteoritical Services

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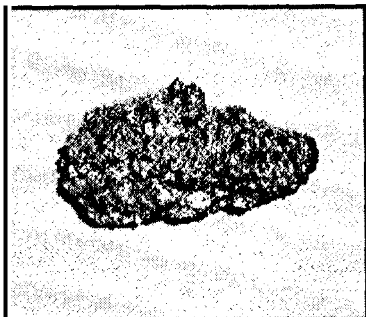
The Chassigny Meteorite

 9K

The Chassigny Meteorite
Copyright Bethany Sciences
New Haven, CT

Met corit c: Chassigny
Location: Chassigny, Haute Marne, France
Fell: October 3,181508:00
Type: Chassignite ($NC)

in 1815, a stone was observed to fall from the sky after loud sonic booms were heard. Although it was estimated that the meteorite originally weighed about 4,000 grams (-9 pounds), there is only about 570 grams preserved of the meteorite today. Chassigny is distinctly different from the other SNC's, so it has been assigned its own signature subgroup, chassignite, to distinguish it from the shergottites and nakhilites.

 44K

Sma l fragment of the Chassigny Meteorite
Copyright 1995 Ron Baalke

Chassigny is the only meteorite in classified as a chassignite. The meteorite pictured directl y above is a smal I fragment from the co] lection of Ron Baalke.

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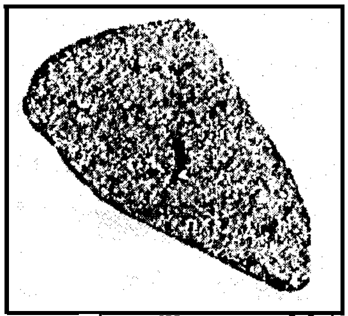
The Shergotty Meteorite



15K

slab of the Shergotty Meteorite.

Meteorite: Shergotty
Location: Shergotty, Gaya, Bihar India
Fell: August 25, 1865, 09:00
Type: Shergottite (SNC)

This 5000 gram (11 pound) meteorite was a witnessed fall, that was observed after detonations were heard.

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The Nakhla Meteorite


36K

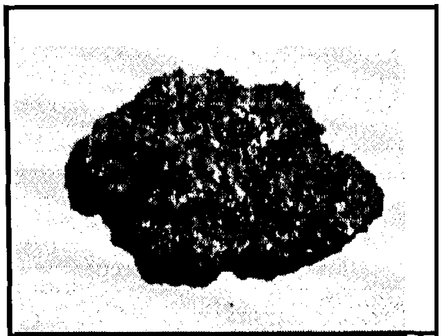
The Nakhla Meteorite

Meteorite: Nakhla
Location: Nakhla, Abu Hommos, Alexandria, Egypt
Fell: June 28,1911,09:00"
Type: Nakhlite (SNC)

A rain of 40 stones fell from the sky in 1911 near Nakhla in Egypt. The falls were preceded by an appearance of a cloud and detonations, frightening local residents, One meteorite hit and killed a dog. The stones ranged in size from 20g to 1813g, and it is estimated a total weight of 40kg (88 pounds) had fallen, the most of any SNC meteorite, Nakhla is the signature meteorite for the nakhlite subgroup of the SNC meteorites, of which there are only two other meteorites in the same classification,


8K

The Nakhla Meteorite


59K

Closeup of a small fragment of the Nakhla Meteorite

 15K

The Nakhla Meteorite
Photo courtesy of the New England Meteoritical Services

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The Lafayette Meteorite

8K

The Lafayette meteorite

Meteorite: Lafayette
location: Lafayette, Tippecanoe County, Indiana, USA
Found: prior to 1931
Type: Nakhlite (SNC)

The exact location of where the Lafayette meteorite fell is not known. The meteorite sat unrecognized in the geological collections in Purdue University for an unknown number of years until it was recognized by O. Farrington in 1931, The 800 gram Lafayette meteorite is very similar to the Nakhla meteorite, which fell in Egypt in 1911, in fact, it has been suggested that the Lafayette meteorite may have been mislabled and be part of the Nakhla fall.

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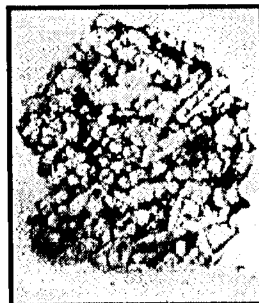
The Governador Valadares Meteorite



42K

Closeup of a slice of the Governador Valadares Meteorite

Meteorite: Governador Valadares
Location: Governador Valadares, Minas Gerais, Brazil
Found: 1958
Type: Nakhlite (SNC)

This 158g meteorite was found by a mineral hunter near the city of Governador Valadares in Brazil. No details on the fall of this meteorite are available. It has been speculated that this meteorite may have been mislabeled and may be part of the Nakhla fall that fell in Egypt in 1911.

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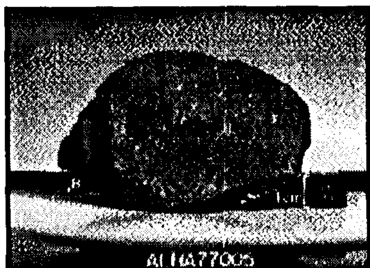
The ALHA 77005 Meteorite

168K

Exterior view of ALHA 77005 showing small patches of fusion crust.
Photo courtesy of Johnson Space Center

Meteorite: ALHA 77005
Location: Allan Hills, Antarctica
Found: 1977
Type: Shergottite (SNC)

This meteorite was the 5th one found in 1977 at Allan Hills in the Antarctic,



184K

Interior sawn surface of ALHA 77005 showing its coarse-grained igneoius texture.
Photo courtesy of Johnson Space Center. '

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baalke@kelvin.jpl.nasa.gov

Yamato 793605 Meteorite

[This spot reserved for a photo of the Yamato 793605 meteorite]

Meteorite: Yamato 793605
location: Yamato Mountains, Antarctica
Fell: 1979
Type: Shergottite (SNC)

This meteorite was recovered by the Japanese near the Yamato Mountains in Antarctica. However, it wasn't until September 1995 that the Japanese geochemists identified Yamato 793605 as a Mars meteorite.

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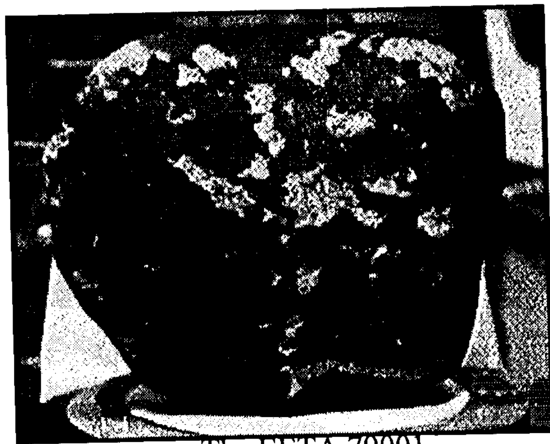
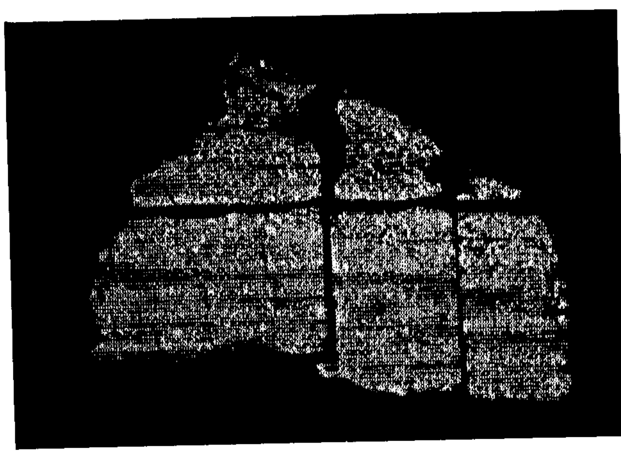
The EETA 79001 Meteorite



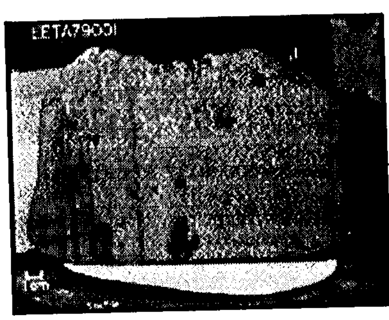
29K

The EETA 79001.
Photo courtesy of Johnson Space Center

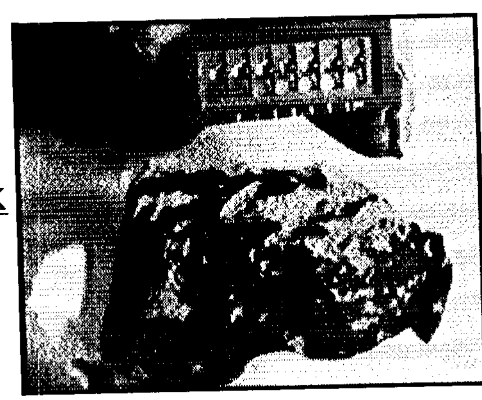
Meteorite: EETA 79001
Location: Elephant Moraine, Antarctica
Found: 1979
Type: Shergottite (SNC)



19K



193K



24K

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The ALH 84001 Meteorite


35K

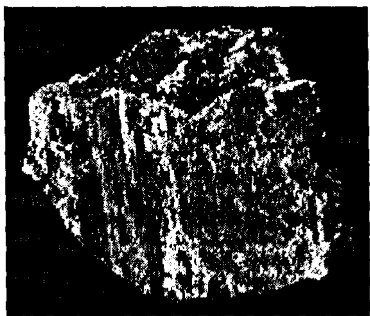
ALH 84001 meteorite
Photo courtesy of Johnson Space Center

Meteorite: ALH 84001
Location: Allan Hills, Far Western Icefield, Antartica
Found: 1984
Type: (SNC)

This is the meteorite causing all of the excitement about life possibly existing on Mars. This meteorite was the first meteorite found by the Antarctic tema in 1984. The meteorite was initially identified as a diogenite, a rare type of achrondite meteorite. It wasn't until October 1993 that David Mittlefehldt caught the error, and properly identified as as an SNC.


18K

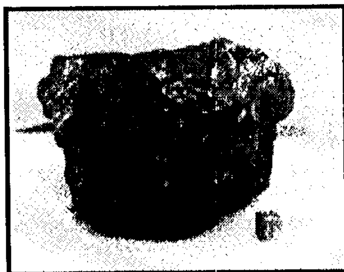
Orange carbonate grains, 100 to 200 microns across, indicate that the meteorite was once immersed in water.


64K

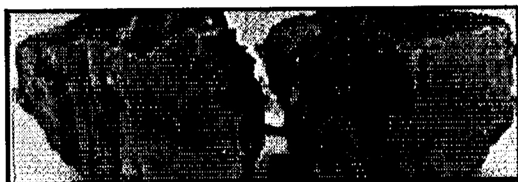
A cut section of ALH 84001. The area exposed measures 10 by 6 centimeters.
Photo courtesy of Johnson Space Center.


194K

Cut section showing splothy appearance of the interior and the broken texture of the fracture zone.


138K

Exterior of the meteorite showing dark brown fusion crust that is eroded in areas exposing the light brown interior.


11K

Two pieces of ALH 84001.

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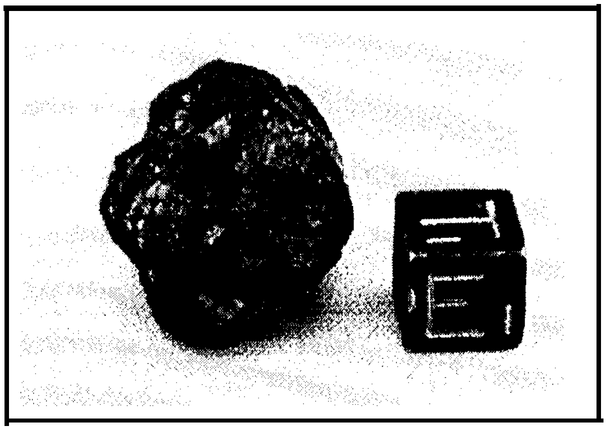
The LEW 88516 Meteorite



7K

Meteorite: LEW 88516
Location: Lewis Cliff, Antarctica
Found: 1988
Type: Shergottite (SNC)

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Searching For Life In Ancient Water Systems of Mars

JPL's Public Affairs Office
presents

"Searching for Life in the Ancient Water Systems of Mars"

A lecture featuring

Dr. Michael Carr
United States Geological Survey

Thursday, August 22,7:30 PM PDT
Jet Propulsion Laboratory
von Karman Auditorium
4800 Oak Grove Blvd.
Pasadena,CA91109

The discovery of possible microfossils found in a Martian meteorite in Antarctica has fostered an even greater excitement in Mars exploration. in this informative lecture, Dr.Carr will discuss developments in biology in the past decade and how these developments contribute to the studies of possible life within the ancient water systems of Mars.

Dr. Carr is a renowned planetary geologist who served as a key member of the Viking project, and is active in several current planetary projects today.

The lecture is free and open to the public,

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Dr. Barlow's findings are being prepared for submission to the Journal of Geophysical Research. She also plans to report on these results at the October meeting of the Division for Planetary Sciences of the American Astronomical Society meeting to be held in Tucson, Arizona,

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Possible Source Craters For Martian Meteorite Found

Contact: Dr. Nadine G. Barlow
Department of Physi cs
University of Central Fl orida
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ngb@physi cs . ucf . edu

FOR I MMEDIATE RE L EASE August 12, 1996

POSSIBLE SOURCE CRATERS FOR MARTIAN METEORITE FOUND

Two possible source craters for the martian meteorite AlJ184001 have been identified through an extensive search of impact craters on Mars, The 1.9-kg (4.2 lb) meteorite, recently identified as showing possible evidence of past martian life, was formed about 4.5 billion years ago and was blasted off of Mars during a meteorite impact about 16 million years ago. Dr. Nadine Barlow, a planetary scientist at the University of Central Florida, identified the two likely source craters through a search of a crater catalog she compiled while doing her graduate work at the University of Arizona in the mid- 1980's.

A number of characteristics of the meteorite helped Dr. Barlow narrow the search for possible source craters. '1 'he 4.5 billion year old age of the meteorite indicated it must have come from the most ancient terrain on Mars, while the 16 million year old ejection age indicates that the crater from which the meteorite was ejected should still show very young features. 1 ;vidence of pre-ejection shock events indicates that one or more large, old craters should be found near the meteorite ejection site, and the presence of carbonates in the meteorite suggests that evidence of water should be present, Previous work by other researchers indicate that martian meteorites can only be ejected either by a very large impact (100-kn~ diameter or larger) if the impact is near-vertical, or by smaller impacts if they strike at an angle close to the horizon. The low angle impacts will create a distinctive elliptical-shaped crater.

Dr. Barlow's crater catalog, which contains information on 42,283 martian impact craters, was used to search for fresh, elliptical impact craters larger than 10-km-diameter and for fresh, circular craters larger than 100-km-diameter on ancient terrain, The search produced 23 possible craters. Dr,. Barlow then used images of the martian surface taken by the Viking Orbiter spacecraft in the mid- 1970's to eliminate those craters which showed evidence of being older than 16-million years. "16 million years may sound like a long time to humans, but for geologic processes it is a very short time period, particularly for a planet like Mars which has apparently experienced little geologic activity over the past billion years" said I)r. Barlow.

The two craters which survived the analysis arc both of the smaller, elliptical crater type. Both arc located in the heavily cratered southern highlands of Mars. The first crater, located in the Sinus Sabaeus region of Mars south of the Schiaparelli impact basin, is 23 x 14.5 km in diameter, displays a pristine ejecta blanket and sharp crater rim, and is superposed on the rim of a much older highly degraded 50-km-diameter crater, Several small channels which formed early in the planet's history arc located nearby, including onc called Evros Vallis. The second possible source crater for ALI 184001 is located cast of the Hesperia Planitia region, is 11 x 9 km in diameter, and also displays a pristine ejecta blanket and sharp crater rim. It is located less than 10 km from an older 25-km diameter crater in an area which also shows some possible evidence of ancient fluvial activity.

The identification of possible source craters for ALI 184001 will allow NASA to focus its efforts on these areas with fut urc lander missions to Mars.

Water Extracted From Mars Meteorites Provide Clue to Red Planet's Past

Paula Cleggett-Haleim
Headquarters, Washington, D.C.
(Phone: .202/ 453-154 -/)

Kari Fluegel
Johnson Space Center, Houston
(Phone: 713/483-5111)

March 13, 1992

RELEASE: 9?-35

METEORITES' WATER PROVIDES CLUE TO RED PLANET'S PAST

A single drop of water rare] y causes excitement in the scientific community, but a few milligrams of liquid extracted from a meteorite may have started to answer one of the great mysteries of planetary science.

Were the channels seen on the surface of Mars carved by once great torrents of rushing water or by some other process?

Dr. Everett Gibson of NASA's Johnson Space Center (JSC), Houston, Planetary Sciences Branch; Dr. Haraldur Karlsson, formerly a National Research Council postdoctoral fellow at JSC; and scientists at the University of Chicago have analyzed drops of water extracted from several meteorites believed to have come from Mars and have concluded that the oxygen isotopes in the water were extraterrestrial.

"it's really a beautiful piece of scientific work to do this analysis," Gibson said, "We are extremel y pleased with the results of this team effort." The results of the team's findings are being published in today's issue of the journal SCIENCE.

Photographs returned to Earth from the Mariner 9 and Viking spacecraft show features that suggest Mars once may have had a water-rich atmosphere and flowing water on its surface. Sometime in its history, however, most of the water apparent] y disappeared, leaving only minute amounts of vapor in the atmosphere.

Through the years, several meteorites have been collected on Earth that scientists have identified as Martian by comparing them to information gleaned by the Viking spacecraft. Six of these meteorites were used in the water extraction procedure.

Gibson said the meteorites were heated in steps in a small vacuum system at JSC to extract trace amounts of water. The water samples were hand-carried to the Universit y of Chicago for analysis of oxygen isotopes. Although the water droplets were less than 1 /64ths of an inch in diameter, it was enough to do the analysis.

The analysis determined that the oxygen isotopes in the water were different from the oxygen isotopes in the silicate portion of the meteorites. In other words, the water had a different parent source than the oxygen in the silicate minerals in the meteorites. "That parent source could have been the Martian atmosphere, an ancient Martian ocean or even a comet that impacted the planet, Gibson said.

The lack of homogeneous oxygen isotopes on Mars supports the theory that Mars dots not have plate tectonics. If such a process had been active on Mars, the oxygen isotopes would have been homogenized as they are on Earth.

Findings from the work completed by the team may answer some questions about the processes operating in the solar system, but the findings raise other questions -- what happened to the water on Mars and does Earth have the same destiny?

"These are large and difficult questions to comprehend," Gibson said, "but perhaps if we can trace the origins and alterations of planetary atmospheres and oceans, the evolution of our solar system may be better understood."

Besides Gibson and Karlsson, who is now in the Department of Geosciences at Texas Tech University, Lubock, team members included Robert N. Clayton and Toshiko K. Mayeda of the Department of Geophysical Sciences and the Enrico Fermi Institute at the University of Chicago.

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Statement from Dan Goldin

Lauri e Boeder
Headquarters, Washington, DC
(Phone: 202/358-1898)

August 6, 1996

RELEASE : 96-159

STATEMENT FROM DANIEL So GOLDIN, NASA ADMINISTRATOR

"NASA has made a startling discovery that points to the possibility that a primitive form of microscopic life may have existed on Mars mom than three billion years ago. The research is based on a sophisticated examination of an ancient Martian meteorite that landed on 1 'arth some 13,000 years ago.

The evidence is exciting, even compelling, but not conclusive. It is a discovery that demands further scientific investigation, NASA is ready to assist the process of rigorous scientific investigation and live] y scientific debate that will follow this discovery.

I want everyone to understand that we arc not talking, about 'little green men, ' These arc extremely small, single- ccl l structures that somewhat resemble bacteria on Earth. 7'here is no evidence or suggestion that any higher 1 ifc form ever existed on Mars.

The NASA scientists and researchers who made this discovery will be available at a news conference tomorrow to discuss their findings. They will outline the step-by-step "detective story" that explains how the meteorite arrived here from Mars, and how they set about looking for evidence of long-ago life in this ancient rock. They will also release some fascinating images documenting their research.

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AAAS News Release

American Association for the Advancement of Science News Release

Signs of Past Life on Mars?
Organic Compounds and Possible Biological Features
Found in Martian Meteorite,
Featured in 16 August 1996 Science

Washington, DC - Ever since scientists learned that water once flowed on Mars, they've wondered whether life might also have flourished on the apparently now-dead planet. In the 16 August issue of Science, McKay et al report the first identification of organic compounds in a Martian meteorite, The authors further suggest that these compounds, in conjunction with a number of other mineralogical features observed in the rock, may be evidence of ancient Martian microorganisms.

The paper's authors are David S. McKay and Everett K, Gibson, Jr., of NASA's Johnson Space Center in Houston, "TX; Kathie L. Thomas-Keprta of Lockheed Martin in Houston, 'TX; Hojatollah Vali of McGill University in Montreal, Quebec; Christopher S. Romanek of the University of Georgia's Savannah River Ecology Laboratory in Aiken, SC; and Simon J. Clemett, Xavier D.F. Chllier, Claude R. Maechlin, and Richard N. Zare of Stanford University in Stanford, CA.

Organic (complex, carbon-based) molecules are the requisite building blocks of life on Earth. 'The authors looked for signs of such molecules and other mineralogical and textural indications of past life within the pore space and fractures of meteorite Allan Hills 84001 (ALH 84001), one of only 12 meteorites identified as having come from Mars. ALH 84001 is the oldest of the Martian dozen, having crystallized from molten rock about 4.5 billion years ago, early in the planet's evolution, and it is the only Martian meteorite to contain significant carbonate minerals. (The carbonates formed sometime after the rock, perhaps about 3.6 billion years ago.)

About 15 million years ago, a major asteroid impact on Mars threw ALH 84001 into space, where it eventually fell onto an ice field in Antarctica about 13,000 years ago. ALH 84001, which shows little evidence of terrestrial weathering, was discovered by meteorite-hunting scientists in 1984 and only recently identified at Martian.

ALH 84001 is riven with tiny fractures resulting primarily from impacts that occurred while the rock was on Mars. The secondary carbonates formed along with some of these fractures. The *Science* authors prepared thin sample sections that included these pre-existing fractures, and found on their surfaces a clear and distinct distribution of polycyclic aromatic hydrocarbons (PAHs), organic molecules containing multiple connected rings of carbon atoms -- the first organic molecules ever seen in a Martian rock. A variety of contamination checks and control experiments indicated that the organic material was indigenous to the rock and was not the result of terrestrial contamination, For example, the authors noted that the concentration of PAHs increases inward, whereas terrestrial contamination likely would have resulted in more PAHs on the exterior of the rock.

The big question is: where did the PAHs come from?

It is thought that PAHs can form one of two ways: non-biologically, during early star formation; or biologically, through the activity of bacteria or other living organisms, or their degradation (fossilization). On Earth, PAHs are abundant as fossil molecules in ancient sedimentary rocks, coal and petroleum, the result of chemical changes that occurred to the remains of dead marine plankton and early plant life. They also occur during partial combustion, such as when a candle burns or food is grilled,

To address the origin of these PAHs, the authors examined the chemistry, mineralogy, and texture of carbonates associated with PAHs in the Martian meteorite. Under the transmission electron microscope, the carbonate globules were seen to contain fine-grained magnetite and iron-sulfide particles, From these and other analyses, the authors developed a list of observations about the carbonates and PAHs that, taken individually, could be explained by non-biological means. However, as they write in their *Science* article, "when considered collectively .... we conclude that [these phenomena] are evidence for primitive life on early Mars." Some of their observations are as follows:

- The higher concentrations of PAHs were found associated with the carbonates.
- The carbonates formed within the rock fissures, about 3.6 billion years ago, and are younger than the rock itself.
- The magnetite and iron-sulfide particles inside the carbonate globules are chemically, structurally and morphologically similar to magnetosome particles produced by bacteria on Earth.
- High-resolution scanning electron microscopy revealed on the surface of the carbonates small (100 nanometers) ovoids and elongated features. Similar textures have been found on the surface of calcite concretions grown from Pleistocene groundwater in southern Italy, which have been interpreted as representing nanobacteria.
- Some earlier reports had suggested that the temperature at which the ALH 184001 carbonates formed was as high as 700° C -- much too hot for any kind of life. However, the isotopic composition of the carbonates, and the new data on the magnetite and iron-sulfide particles, imply a temperature range of 0° to 80°C, cool enough for life.
- The magnetite -- a mineral which contains some ferric (Fe^{3+}) iron, perhaps indicating formation by oxidation (the addition of oxygen) -- and iron sulfide -- a mineral that can be formed by reduction (the loss of oxygen) -- were found in close proximity in the Martian meteorite. On Earth, closely associated mineralogical features involving both oxidation and reduction are characteristic of biological activity.

Science is the official journal of the American Association for the Advancement of Science (AAAS) in Washington, DC, the world's largest general science organization.

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Meteorite Yields Evidence of Primitive Life on Early Mars

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August 7, 1996

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RELEASE: 96-160

METEORITE YIELDS EVIDENCE OF PRIMITIVE LIFE ON EARLY MARS

A NASA research team of scientists at the Johnson Space Center (.ISC), Houston, TX, and at Stanford University, Palo Alto, CA, has found evidence that strongly suggests primitive life may have existed on Mars more than 3.6 billion years ago,

The NASA-funded team found the first organic molecules thought to be of Martian origin; several mineral features characteristic of biological activity; and possible microscopic fossils of primitive, bacteria-like organisms inside of an ancient Martian rock that fell to Earth as a meteorite. This array of indirect evidence of past life will be reported in the August 16 issue of the j ournal Science, presenting the investigation to the scientific community at large for further study.

The two-year investigation was co-led by JSC planetary scientists Dr. David McKay, Dr. Everett Gibson and Kathie Thomas-Keprta of Lockheed-Martin, with the major collaboration of a Stanford team headed by Professor of Chemistry Dr. Richard Zare, as well as six other NASA and university research partners.

"'1'here is not any onc finding that leads us to believe that this is evidence of past life on Mars. Rather, it is a combination of many things that we have found," McKay said. "They include Stanford's detection of an apparently unique pattern of organic molecules, carbon compounds that arc the basis of life. We also found several unusual mineral phases that arc known products of primitive microscopic organisms on Earth. Structures that could be microsopic fossils seem to support all of this. The relationship of all of these things in terms of location - within a few hundred thousandths of an inch of one another - is the most compelling evidence. "

"It is very difficult to prove life existed 3.6 billion years ago on Earth, let alone on Mars," Zare said. "The existing standard of proof, which wc think wc have met, includes having an accurately dated sample that contains native microfossils, mineralogical features characteristic of life, and evidence of complex organic chemistry. "

"For two years, we have applied state-of-the-art technology to perform these analyses, and we believe wc have found quite reasonable evidence of past life on Mars," Gibson added. "WC don't claim that wc have conclusively proven it. We are putting this evidence out to the scientific community for other invest igators to verify, enhance, attack -- disprove if they can -- as part of the scientific process. '1'hen, within a year or two, wc hope to resolve the question one way or the other."

"What wc have found to be the most reasonable interpretation is of such radical nature that it will only be accepted or rejected after other groups either confirm our findings or overturn them," McKay added.

The igneous rock in the 4.2-pound, potato-sized meteorite has been age-dated to about 4.5 billion years, the period when the planet Mars formed. 'l'he rock is believed to have originated underneath the Martian surface and to have been extensively fractured by impacts as meteorites bombarded the planets in the car] y inner solar system. Between 3.6 billion and 4 billion years ago, a time when it is general] y thought that the planet was warmer and wetter, water is believed to have penetrated fractures in the subsurface rock, possibly forming an underground water system.

Since the water was saturated with carbon dioxide from the Martian atmosphere, carbonate minerals were deposited in the fractures. 'l'he team's findings indicate living organisms also may have assisted in the formation of the carbonate, and some remains of the microscopic organisms may have become fossilized, in a fashion similar to the formation of fossils in limestone on Earth. Then, 16 million years ago, a huge comet or asteroid struck Mars, ejecting a piece of the rock from its subsurface location with enough force to escape the planet. For millions of years, the chunk of rock floated through space. It encountered Earth's atmosphere 13,000 years ago and fell in Antarctica as a meteorite.

It is in the tiny globs of carbonate that the researchers found a number of features that can be interpreted as suggesting past life. Stanford researchers found easily detectable amounts of organic molecules called pol ycyclic aromatic hydrocarbons (l'Al Is) concentrated in the vicinity of the carbonate. Researchers at JSC found mineral compounds commonly associated with microscopic organisms and the possible microscopic fossil structures.

The largest of the possible fossils are less than 1/100 the diameter of a human hair, and most arc about 1/1 000 the diameter of a human hair - small enough that it would take about a thousand laid end-to-end to span the dot at the end of this sentence. Some arc egg-shaped while others arc tubular. in appearance and size, the structures are strikingly similar to microscopic fossils of the tiniest bacteria found on Earth.

The meteorite, called ALH 184001, was found in 1984 in All an 1 Iills ice field, Antarctica, by an annual expedition of the National Science Foundation's Antarctic Meteorite Program. It was preserved for st udy in J SC'S Meteorite]'recessing 1.aboratory and its possible Martian origin was not recognized until 1993. It is onc of only 12 meteorites identified so far that match the unique Martian chemistry measured by the Viking spacecraft that landed on Mars in 1976, AI .J 184001 is by far the oldest of the 12 Martian meteorites, more than three times as old as any other.

Many of the team's findings were made possible onl y because of very recent technological advances in high- resolution scanning electron microscopy and laser mass spectrometry. Only a few years ago, many of the features that they report were undetectable. Although past studies of this meteorite and others of Martian origin failed to detect evidence of past life, they were generally performed using lower levels of magnification, without the benefit of the technology used in this research. The recent di scovery of extremel y small bacteria on Earth, called nanobacteria, prompted the team to perform this work at a much finer scale than past efforts.

The nine authors of the Science report include McKay, Gibson and Thomas-Keprta of JSC; Christopher Romanek, formerly a National Research Council post-doctoral fellow at JSC who is now a staff scientist at the Savannah River Ecology Laboratory at the Universit y of Georgia; Hojatollah Vali, a National Research Council post-doctoral fellow at JSC and a staff scientist at McGill Universit y, Montreal, Quebec, Canada; and Zare, graduate students Simon J. Clemett and Claude R. Maechling and post-doctoral student Xavier Chillier of the Stanford University Department of Chemistry.

The team of researchers includes a wide variet y of expertise, including microbiology, mineralogy, analytical techniques, geochemistry and organic chemistry, and the analysis crossed all of these disciplines. Further details on the findings presented in the Science article include:

- Researchers at Stanford University used a dual laser mass spectrometer -- the most sensitive instrument of its type in the world -- to look for the presence of the common family of organic molecules cal led PAl Is. When microorganisms die, the complex organic molecules that they contain frequentl y degrade into PA11s. PAl 1s arc often associated with ancient sedimentary rocks, coals and petroleum on Earth and can be common air pollutants. Not only did the scientists find PAl Is in easily detectable amounts in Al .I 184001, but they found that these molecules were concentrated in the vicinity of the carbonate globules. 'l'his finding appears consistent with the proposition that they are a result of the fossilization process, In addition, the unique composition of the meteorite's PA11s is cons. stent with what the scientists expect from the fossilization of very primitive microorganisms. On Earth, PAl Is virtual l y always occur in thousands of forms, but, in the meteorite, they are dominated by only about a half-dozen different compounds, The simplicity of this mixture, combined with the lack of light- weight PA11s like napthalene, also differs substantiall y from that of PA] 1s previous] y measured in non-Martian meteorites,

[1 The team found unusual compounds -- iron sulfides and magnetite -- that can be produced by anaerobic bacteria and other microscopic organisms on Earth. The compounds were found in locations directly associated with the fossil-like structures and carbonate globules in the meteorite. 1 Extreme conditions -- conditions very unlikely to have been encountered by the meteorite -- would have been required to produce these compounds in close proximity to one another if life were not involved. The carbonate also contained tiny grains of magnetite that are almost identical to magnetic fossil remnants often left by certain bacteria found on 1 Earth. Other minerals commonl y associated with biological activity on Earth were found in the carbonate as well.

The formation of the carbonate or fossils by living organisms while the meteorite was in the Antarctic was deemed unlikely for several reasons. The carbonate was age dated using a parent-daughter isotope method and found to be 3,6 billion years old, and the organic molecules were first detected well within the ancient carbonate. in addition, the team analyzed representative samples of other meteorites from Antarctica and found no evidence of fossil-like structures, organic molecules or possible biological y produced compounds and minerals similar to those in the AI.1 184001 meteorite. The composition and location of PAl 1s organic molecules found in the meteorite also appeared to confirm that the possible evidence of life was extraterrestrial. No PAl 1s were found in the meteorite's exterior crust, but the concentration of PA] Is increased in the meteorite's interior to levels higher than ever found in Antarctica. Higher concentrations of PAl Is would have likely been found on the exterior of the meteorite, decreasing toward the interior, if the organic molecules arc the result of contamination of the meteorite on Earth.

Additional information may be obtained at 1 p.m. EDT via the Internet at

http: //www.jsc.nasa.gov/pao/flash/

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President Clinton Statment Regarding Mars Meteorite Discovery

THE WHITE HOUSE
Office of the Press Secretary
For Immediate Release
August 7, 1996

REMARKS BY THE PRESIDENT
UPON DEPARTURE

The South Lawn
1:15 P.M. EDT

THE PRESIDENT: Good afternoon. I'm glad to be joined by my science and technology adviser, Dr. Jack Gibbons, to make a few comments about today's announcement by NASA.

This is the product of years of exploration and months of intensive study by some of the world's most distinguished scientists. Like all discoveries, this one will and should continue to be reviewed, examined and scrutinized. It must be confirmed by other scientists. But clearly, the fact that something of this magnitude is being explored is another vindication of America's space program and our continuing support for it, even in these tough financial times. I am determined that the American space program will put it's full intellectual power and technological prowess behind the search for further evidence of life on Mars.

First, I have asked Administrator Goldin to ensure that this finding is subject to a methodical process of further peer review and validation. Second, I have asked the Vice President to convene at the White House before the end of the year a bipartisan space summit on the future of America's space program. A significant purpose of this summit will be to discuss how America should pursue answers to the scientific questions raised by this finding. Third, we are committed to the aggressive plan we have put in place for robotic exploration of Mars, America's next unmanned mission to Mars is scheduled to lift off from the Kennedy Space Center in November. It will be followed by a second mission in December. I should tell you that the first mission is scheduled to land on Mars on July the 4th, 1997 -- Independence Day.

It is well worth contemplating how we reached this moment of discovery. More than 4 billion years ago this piece of rock was formed as a part of the original crust of Mars. After billions of years it broke from the surface and began a 16 million year journey through space that would end here on Earth. It arrived in a meteor shower 13,000 years ago. And in 1984 an American scientist on an annual U. S. government mission to search for meteors on Antarctica picked it up and took it to be studied, Appropriately, it was the first rock to be picked up that year -- rock number 84001.

Today, rock 84001 speaks to us across all those billions of years and millions of miles. It speaks of the possibility of life. If this discovery is confirmed, it will surely be one of the most stunning insights into our universe that science has ever uncovered. Its implications are as far-reaching and awe-inspiring as can be imagined. Even as it promises answers to some of our oldest questions, it poses still others even more fundamental.

We will continue to listen closely to what it has to say as we continue the search for answers and for knowledge that is as old as humanity itself but essential to our people's future.

Thank you.

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NSF Statment Regarding Possible Early Life on Mars

Contact : Mary Hanson (703) 306-10`10 August 7, 1996

Statement by

DR , NE AL LANE
D] RECTOR, NAT I ONAL SC I ENCE FOUNDATI ON

On Announcement Regarding Possible Early Life on Mars

Today's announcement of scientific evidence for possible car] y life on Mars reignites the excitement of discovery and pioneering spirit which motivates all science, and reinforces the need to continue our national investment in scientific research.

The 4,5-billion-year-old meteorite which offers this unprecedented potential for new scientific knowledge was found in Antarctica during an ongoing National Science Foundat ion research project. It is ironic that wc found signposts to possible life outside of earth by searching in the most remote location on earth. Antarctica is 'the mother lode' of meteorites, and has yielded more than 16,000 meteorites so far -- close to one-half of the world's scientific samples. The annual hunt for Antarctic meteorites is like a bargain-priced space mission that lets scientists explore extraterrestrial worlds without leaving their home planet. Occasional] y one of the samples evolves into a treasure of new knowledge that reveals itself s1owI y and gradually, through scientific scrutiny. In the case of the meteorite di scussed today, it was only by using the most recent and advanced scientific equipment that researchers were able to begin to unlock its m ysteries. "1 'he NSl~-funded science team which discovered the meteorite -- led by researchers Bill Cassidy and John Schutt of the University of Pittsburgh -- were not even focused on the implications of organic life on other planets when they plucked the now-famous space rock from the frozen continent in 1984.

In spite of the many impressive scientific advances that seem to occur at an ever faster pace, there is still so much wc don't know about our universe and the life it holds. '1-he results announced today are not definitive, as the research team itself points out. Rigorous science will continue to unfold the nature and origins of life, whether on earth or elsewhere in the universe,

Wc live in a golden age of science, which we hope will continue to unlock the secrets of the unknown for the benefit of all humankind.

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NSF Statment Regarding Possible Early Life on Mars

Contact : Mary Hanson (703) 306-1070 August '1, 1996

Statement by

DR. NEAL LANE
DIRECTOR, NATIONAL SCIENCE FOUNDATION

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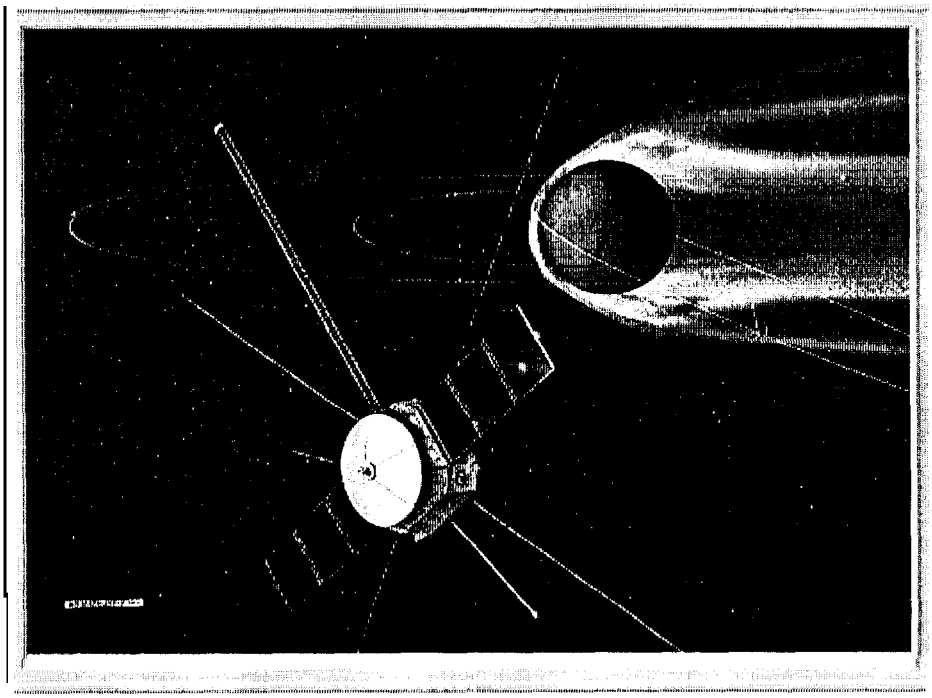
PLANET-B (FY 1998)



The third interplanetary mission after Halley's commet exploration by ISAS is a mission to send PLANET-B Mars orbiter. It is primarily for the observation of the interaction between the Martian atmosphere and solar wind.

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Missions by M-V Launcher

PLANET-B / Center for PLAnning and INformation Systems, the institute of Space and Astronautical Science. /webmaster@www.isas.ac.jp